COOPERATION SUPPORT IN A DYADIC SUPPLY CHAIN

François Galasso, Caroline Thierry

COOPERATION SUPPORT IN A DYADIC SUPPLY CHAIN

François GALASSO
LAAS-CNRS, Université de TOULOUSE
7 avenue du Colonel ROCHE
31077 Toulouse Cedex 4
galasso@univ-tlse2.fr

Caroline THIERRY
Université de TOULOUSE, IRIT
5 allées Antonio MACHADO
31058 TOULOUSE
thierry@univ-tlse2.fr

ABSTRACT: *To improve the supply chains performance, taking into account the customer demand in the tactical planning process is essential. It is more and more difficult for the customers to insure a certain level of demand over a medium term period. Then it is necessary to develop methods and decision support systems to reconcile the order and book processes. In this context, this paper aims at introducing a collaboration support tool and methodology dedicated to a dyadic supply chain. This approach aims at evaluating in term of risks different demand management strategies within the supply chain using a simulation dedicated tool. The evaluation process is based on an exploitation of decision theory and game theory concepts and methods.*

KEYWORDS: ***supply chain,*** *simulation, collaboration, decision theory, risk*

1. INTRODUCTION

Implementation of cooperative processes for supply chain management is a central concern for practitioners and researchers. In aeronautics, this cooperative processes are characterised by a set of point-to-point relationship (customer/supplier) with a partial information sharing (François and Galasso, 2005). More over, due to a big difference among the supply chain actors in terms of maturity it is more or less difficult to implement collaborative processes for the different companies. In particular, SMEs have a partial vision of the supply chain and a lack of efficient tools to analyse the uncertain information transmitted from the customers and thus to be able to take advantage of this information in a cooperative way.

The good comprehension of the demand is a key parameter for the efficiency of the internal processes and the upstream supply chain (Bartezzaghi and Verganti, 1995). Thus it is important to provide the suppliers with methods and systems for a better understanding of the demand and a better integration in the supply chain planning processes.

The introduction of slacks in the planning or demand management processes enables the integration of the imprecision on the customer demand (Galasso, 2007). This strategy enables a protection against the demand variations; nevertheless it induces high inventory level.

In this paper, we aim at providing to the aeronautics suppliers a decision support to take advantage of the information provided by the customers in a cooperative perspective even if this information is uncertain. Thus, we propose a risk evaluation approach which is based on a simulation of planning process of the point-to-point supply chain relationship. More precisely we are concerned with the impact of the demand management processes in the planning process.

After an introduction of the system under study and the addressed problematics (§2) we propose a state of art (§3) on collaboration in supply chain management and Supply Chain Risk Management. Then we describe the simulation approach proposed to evaluate the risks linked to the choice of the demand management and demand transmission strategies. (§4). At last, we illustrate the proposed methodology on a case study (§5).

2. SYSTEM UNDER STUDY AND PROBLEMATICS

In this paper we are concerned with a dyadic supply chain with a supplier (SME) and a customer. In the context of this study (i.e. figure 1.), the customer transmit a demand plan to the supplier.

During the customer planning process a frozen horizon is considered (within this frozen horizon no decision can be revised). Firm demands are transmitted to the supplier within this frozen horizon. *Firm demands* are related to the period closed to the present time. They are defined on a given time horizon, called firm horizon (*FH*).

After this planning horizon, decisions can be revised within a given interval. This interval is part of the cooperation partnership between the supplier and the customer. We call “forecast” or “flexible” demands the couple (forecast value, flexibility level) which is transmitted to the supplier. The flexibility level is expressed in term of percentage of variation around the forecast value. The minimum and maximum values of the flexibility interval will be called “flexibility bounds” here after. These flexible demands are defined on a given time horizon, called flexible horizon (*LH*) which is part of the cooperation process between the customer and the supplier. Firm and flexible orders are transmitted to the supplier with a given periodicity.

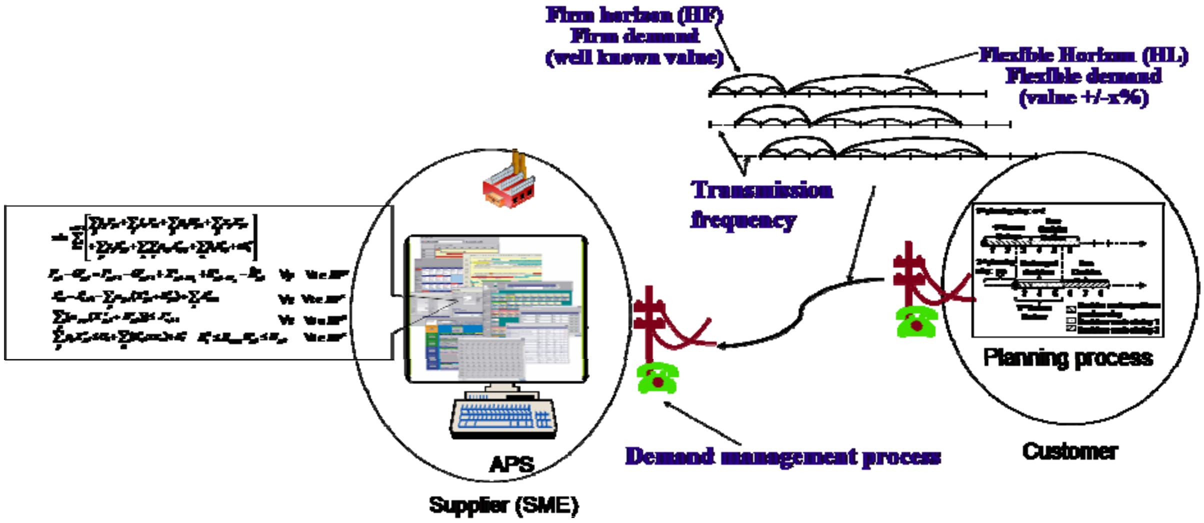

Figure 1. Study positioning

More over, in this paper, concerning the planning process at a given moment, the supplier is supposed to use a given optimisation procedure using an ad hoc model via an Advanced Planning System, which is not the object of this study. The APS compute determinist data thus he has to pre-compute the flexible demands transmitted by the customer as a couple (value, flexibility level). Different types of behaviours can be envisage according to the degree of knowledge of the supplier on his customer's behaviour (for example, trend to overestimation or to underestimation)

3. STATE OF ART

Supply chain management emphasises the necessity to establish collaborative interactions that rationalize or integrate the forecasting and management of demand, reconcile the order and book processes, and mitigate risks. This awareness of both academics and practitioners alike is linked, in particular, to the Bullwhip effect whose influence has been clearly shown and studied (Lee *et al*., 1997; Moyaux, 2004).
Recently, many organizations have emerged to encourage trading partners to establish collaborative interactions (that rationalize or integrate their demand forecasting/management, and reconcile the order-book processes) and to provide standards (that could support collaboration processes): RosettaNet (Rosetta, 2007), Voluntary Inter-industry Commerce Standards Association (Vics, 2007), ODETTE (Odette, 2007), etc. On the other hand, McCarthy and Golicic (2002) consider that the process of collaboration brought by the CPFR (Collaborative Planning, Forecasting and Replenishment) model is too detailed. They suggest instead that the companies should make regular meetings to discuss the forecast with the other supply chain partners and that they develop shared forecast. So there is a need to evaluate these standards.

In the same way, many recent research papers are devoted to cooperation in the context of supply chain management.
Under the heading of cooperation, authors list several aspects. One of these aspects on which we focus in this paper is cooperation through information sharing. Using Huang *et al.* (2003) literature review, we can distinguish different classes of information which have a role in the information sharing literature: (1) product information, (2) process information, (3) lead time, (4) cost, (5) quality information, (6) resource information, (7) order and inventory information, (8) Planning (forecast) information. Another aspect of cooperation concerns extending of the information sharing to collaborative forecasting and planning systems (Dudek and Stadtler, 2005; Shirodkar and Kempf, 2006). In this paper, we will focus on planning information sharing (forecast) (Lapide, 2001; Moyaux, 2004).

In this paper we focus on the risk evaluation of the cooperative planning process within a dyadic supply chain. Supply chain Risk Management (SCRM) is the "management of external risks and supply chain risks through a co-ordinated approach between the supply chain partners in order to reduce supply chain vulnerability as a whole" (Christopher, 2003). Up to now there is still a "lack of industrial experience and academic research for supply chain risk management" identified by (Ziegenbein and Nienhaus, 2004) even if, since 2004, there has been an increasing number of publications in this field. More specifically, the question of the risk management related to the use of Advanced Planning Systems has to be studied (Ritchie *et al.,* 2004).

Nevertheless, little attention has been paid to risk evaluation of new collaborative processes (Småros, 2005, Brindley, 2004, Tang et al 2006). This is also true when planning processes under uncertainty are concerned (Mula *et al.,* 2006) even if the problem of the management tactical planning with an APS has been introduced by (Rota *et al.,* 2002) and the problem of robustness of this problem has been studied by (Génin *et al.,* 2007).

4. DECISION AND COLLABORATION SUPPORT UNDER UNCERTAINTY

In order to provide a collaborative decision support to both actors in the dyadic supply chain, we present an approach for risk evaluation of:

- the choice of the planning strategies (demand management) by the supplier and
- the choice of demand transmission strategies (size of the firm horizon) by the customer.

This risk evaluation is performed considering uncertainty on the demand. This uncertainty concerns firstly the global trends of evolution of the market. These trends are pervaded with uncertainty as it is difficult to evaluate if the market will be strong, weak or temporarily increasing (with a demand peak). Furthermore, the demand at for specific period is within an interval which bounds are the minimal and maximal values of the flexibility associated to the demand.
This risk evaluation process (§4.1) uses a simulation tool which embeds a model for the behaviour of both actors of the considered supply chain (§4.2).

4.1. Risk evaluation approach using simulation

Within a dyadic supply chain, both actors have to determine they behaviours (internal strategies) to design a common cooperative strategy.

The main problem of the *supplier* is to choose a planning strategy concerning the demand management in order to take into account the demand transmitted by the customer in its planning process.
Regarding the *customer* demand management process, an important decisional lever is the length of the firm and flexible horizon. Through this lever, the supplier has more or less visibility on the demand and thus more or less time to react and adapt its production process.

For each actor of the dyadic supply chain, the different potential strategies are evaluated and compared for several scenarios of demand. At the supplier level, the definition of a cost model (a cost being associated to each parameter of the model) enables the calculation of *the global gain* obtained by the use of each strategy regarding each scenario. This gain can be considered as representative, at an aggregated level, of the combination of all indicators. The values issued from the global gain indicator enable the manager responsible of the planning process to evaluate the risks associated to the planning policies that he envisaged. At the customer level, the performance indicator used is the *cost of backorders*.
However, the best policy can be different depending on the considered scenario of demand evolution. Thus, it is necessary to compare each strategy considering the whole set of scenarios. In such a context, such a comparison is possible using a decision criterion in order to aggregate the indicators obtained for each scenario. In the frame of the problem under study, it is hardly possible to associate probabilities to the occurrence of each scenario. Thus, the evaluation can be done through the use of several decision criteria (which may lead to different results) based on the gain obtained after the simulation of each scenario: Laplace's criterion (average), Wald's criterion (pessimistic evaluation), Hurwicz's criterion (weighted sum of pessimistic and optimistic evaluation), Savage's criterion (minimising the maximum regret), etc. The results given by the different criteria can gathered into a risk diagram on which the manager in charge of the planning process can base its decision making (Mahmoudi, 2006). A general diagram is presented and detailed in figure 2.

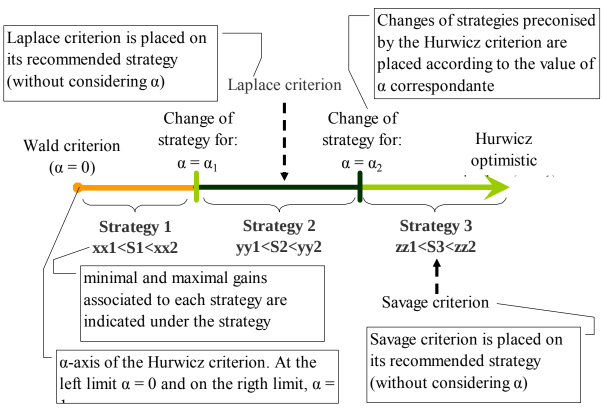

Figure 2. General risk diagram

In this diagram, the demand management strategies are positioned regarding the risk propension of the decision maker: these strategies are thus positioned on an axis corresponding to the values of α between 0 and 1 and noted α-axis. The evolution of the value of this criterion as a function of α for each strategy is represented on a curve following the formula of the Hurwicz criterion: $H_S(\alpha) = (1-\alpha)\, m_S + \alpha\, M_S$ (with m_S the minimal gain and M_S the maximal gain obtained applying the strategy S). From this curve, the values of α_i indicating a change in the proposed strategy can be determined. Then, the strategies are specified on the diagram. For each strategy, the associated minimal and maximal gains are given. Furthermore, if the represented strategies are proposed by other criteria (Laplace or Savage), these criteria are attached to the relevant strategy (without considering the value of α).

Moreover, in order to engage a cooperative process, it is necessary to consider the objectives of both actor of the supply chain simultaneously. To perform this multi-actor decision making process, we propose a game theory based approach. A first step consists in the determination of the propension to risk by the decision maker (using the risk evaluation approach presented here before). Then we simulate a two actors game in order to obtain a Nash equilibrium (in game theory, the Nash equilibrium is a solution in which no player has anything to gain by changing only his or her own strategy unilaterally).

4.2. Behaviour model within the simulation tool

In order to model the dynamic behaviour of both actors we define:

- The behaviour models of the customer enabling the calculation of firm demand and forecasts transmitted to the supplier,
- The behaviour models of the supplier embedding:
    - The management process of the demand
    - The planning process

The simulation of these behaviours relies on a fixed step time advance. This period corresponds to the replanning period.

4.3.1 Model of the customer's behaviour

The evolution of the customer demand is simulated by a model enabling a macroscopic point of view of the customer's behaviour. This model permits the calculation of the customer demand at each simulation step. The principle of this model is illustrated hereafter in an example (figure 3).

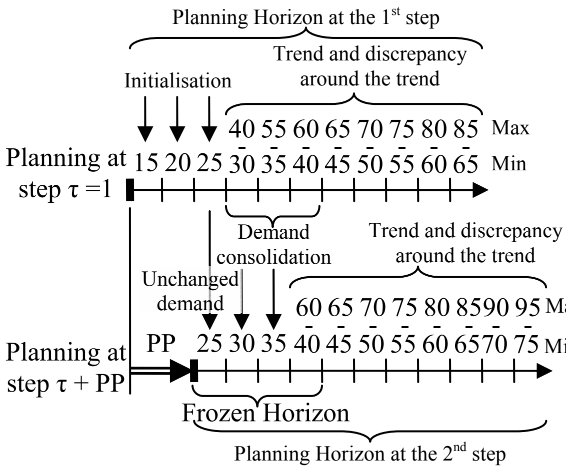

Figure 3. customer's behaviour model

The flexible demand transmitted to the supplier is established taking into account a trend and a discrepancy around this trend. The firm demand is calculated according to the flexible demand established at the previous planning step and so-called hereinafter: the consolidation process of the demand. During the foremost simulation step, the demand is initialised by the calculation of a flexible demand from the trend and the discrepancy over the whole planning horizon and then, the consolidation process is rolled-on over the firm horizon.

In the example depicted by figure 3, the trend is linear and grows-up at a 5 produced units per period rate. The discrepancy is, in a simplified way, of +/- 5 units at each period. The modelled scenario is the one in which the customer overestimates the flexible demand. The firm demand is therefore calculated as equal to the lower bound of the transmitted flexible demand at the previous simulation step.

The customer demand is noted $D_{p,t}^{\tau}$. The discrepancy is modelled by an interval limited by the following bounds:

- $\underline{D}_{p,t}^{\tau}$, is the lower bound of the tolerated discrepancy over the flexible demand,
- $\overline{D}_{p,t}^{\tau}$, is the upper bound.

The demand expressed at each period are always within the interval defined by $\left[\underline{D}_{p,t}^{\tau},\overline{D}_{p,t}^{\tau}\right]$ at each end-item p, period t and planning step τ. They are modelled as the following (1):

$$\begin{cases} D_{p,t}^{\tau}, \quad \forall p, \forall t \in FH^{\tau} \\ D_{p,t}^{\tau} \in \left[\underline{D}_{p,t}^{\tau},\overline{D}_{p,t}^{\tau}\right] \forall p, \forall t \in LH^{\tau} \end{cases} \quad (1)$$

The evolution of the demand between two successive steps is formalised by the following relations:

$$D_{p,t}^{\tau} = D_{p,t}^{\tau-PP} \ \forall p \ \ \forall t \in \left\{FH^{\tau-PP} \cap FH^{\tau}\right\} \quad (2)$$

$$D_{p,t}^{\tau} \in \left[\underline{D}_{p,t}^{\tau-PP},\overline{D}_{p,t}^{\tau-PP}\right] \forall p \ \ \forall t \in \left\{LH^{\tau-PP} \cap FH^{\tau}\right\} \quad (3)$$

$$\left[\underline{D}^{\tau}_{p,t},\overline{D}^{\tau}_{p,t}\right]=\left[\underline{D}^{\tau-PP}_{p,t},\overline{D}^{\tau-PP}_{p,t}\right]\forall p \quad \forall t\in\left\{LH^{\tau-PP}\cap LH^{\tau}\right\} \tag{4}$$

Equation (2) shows that the firm demands are not modified between two successive planning steps. New firm demands (as they result from the consolidation process) remain consistent with their previous "flexible" values (3). The bounds of the flexible do not change between two planning steps (4).

4.3.2 Model of the supplier's behaviour

The *management of the supplier's demand* process enables the definition of the demand that will be taken into account in the supplier's planning process in its deterministic form. This management process depends on the uncertainty associated to the demand corresponding to the flexibility interval associated to the customer's demand. Thus, regarding the considered horizon (i.e. firm or flexible), the supplier will satisfy either equation 5 or 6.

$$\hat{D}^{\tau}_{p,t} = D^{\tau}_{p,t} \ \forall p \ \forall t \in FH^{\tau} \tag{5}$$

$$\hat{D}^{\tau}_{p,t} = f(\underline{D}^{\tau}_{p,t},\overline{D}^{\tau}_{p,t}) \ \forall p \ \forall t \in LH^{\tau} \tag{6}$$

in which $\hat{D}^{\tau}_{p,t}$ is the deterministic demand on which the planning process is based. The definition of a value $\hat{D}^{\tau}_{p,t}$ is made through the use of the demand management strategy *f* as described in equation 6.

The planning behaviour is modelled as a planning problem using a mixed integer linear planning model (similar to those used in Advanced Planning Systems (APS)). Such a model is based on the one detailed in (Galasso *et al.,* 2006). The objective function (7) of this model has been adapted in order to maximise the gain calculated at each planning step. This model aims to conserve a certain commonality and possess the following characteristics: multi-product, multi-components, possibility to adjust internal capacity through the use of extra-hours, change the workforce from one to two or three-shifts-work and subcontracting a part of the load.

The decision variables are introduced:

- $X_{p,t}$: internal production of final product *p* at period *t*.
- $ST_{p,t}$: subcontracted production of final product *p* at period *t*.
- HS_t: extra-hours used at period *t*.
- $B_{a,t}$: (binary variables) = 1 if action *a* is used in order to modify the workforce at period *t* and = 0 otherwise.

These decisions are linked with the following state variables:

- $I^{+}_{p,t}$; $I^{-}_{p,t}$: inventories and backorders levels at the end of period *t* for the final product *p*.
- $J_{c,t}$: component inventory at period t.
- $A_{s,c,t}$: purchases of component *c* bought at supplier *s* to be delivered at period *t*.

The model is based on the following data:

- *CN*: nominal capacity available at each period *t*.
- *{a}*: set of actions that can be activated in order to adjust the capacity levels (i.e. 2 or 3-shifts-work) through the use of $B_{a,t}$.
- $\hat{D}_{p,t}$: deterministic demand of final product *p* at period *t* defined by the supplier.
- R_p: unitary production lead time for final product *p*.
- $\alpha_{p,c}$: bills of material coefficient linking final products *p* and components *c*.

The planning model is defined hereafter in (7):

$$\max \sum_{t=\tau}^{\tau+HP-1}\left[\begin{array}{l}\sum_p v_p V_p - \sum_p h_p I^{+}_{p,t} - \sum_c c_c J_{c,t} - \sum_p b_p I^{-}_{p,t} - \sum_p u_p X_{p,t}\\ -\sum_p st_p ST_{p,t} - \sum_c\sum_s f_{s,c} A_{s,c,t} - \sum_a o_a B_{a,t} - eHS_t\end{array}\right] \tag{7}$$

is subject to:

$$I^{+}_{p,t} - I^{-}_{p,t} = I^{+}_{p,t-1} - I^{-}_{p,t-1} + X_{p,t-LP} + ST_{p,t-LS} - \hat{D}_{p,t} \quad \forall p, t \in HP \tag{8}$$

$$\sum_p R_p X_{p,t} \le CN + \sum_a (B_{a,t} \times SC_a) + HS_t \ \forall t \in HP \tag{9}$$

$$J_{c,t} = J_{c,t-1} - \sum_p \alpha_{p,c}(X_{p,t} + ST_{p,t}) + \sum_s A_{s,c,t} \quad \forall t \in HP \tag{10}$$

$$\sum_p \alpha_{p,c}(X_{p,t} + ST_{p,t}) \le J_{c,t-1} \quad \forall t \in HP \tag{11}$$

$$HS_t \le HSMax \ \forall t \in HP \tag{12}$$

The objective function (7) maximises the gain obtained through the plan established at each planning step. v_p is the gain resulting from the deliveries of each product *p*. h_p, hc_c, b_p, u_p, st_p, $f_{s,c}$, o_a, *e*, are the unitary costs associated to the relevant decisions. Equation (8) links production quantities (subcontracted or not) and the levels of inventories and backorders. The lead times (LP standing for internal production and LS for the subcontracted production) are also introduced in equation (8). Moreover in that equation, the deterministic demand $\hat{D}_{p,t}$ is taken into account for the simulation of the planning process. The amount of production available at each period is limited by the capacity defined with constraint (9). A standard capacity *CN* is available at each period. An amount of extra-hours HS_t and an overcapacity SC_a (introduced through the use of actions defined in *{a}* and activated through $B_{a,t}$) can be added to the standard capacity. This constraint shows that resources are shared among products. Equation (10) enables the calculation of the inventory levels of components according to the purchases $A_{s,c,t}$ and the consumption of components linked to the internal and subcontracted production with the coefficients of the bills of materials $\alpha_{p,c}$. Constraint (11) ensure the consistency between the requirements and the inventory levels of components. Extra-hours are limited by (12) by a maximum value *HSMax*. All these constraints are defined at each period (time bucket) of the planning horizons.

Each decision variable has its own dynamics and, similarly to the management of the customer demand, can be subject to a specific anticipation delay corresponding to the necessary organisational requirements previous to the applicability of such decisions.

5. ILLUSTRATIVE EXAMPLE

In this example, the collaborative decision making process detailed in section 4 is applied to an academic example. The example considers the case of a single final product representative of the aggregation at the tactical level of a family of end-items. On the one hand, different scenarios corresponding to different trends of the market are considered. On the other hand, the supplier has two decisional levers in order to adjust its capacity and the customer a decision lever which is the different firm horizon length. Thus, beyond its internal capacity, the supplier can use extra-hours and subcontract a part of its load. The objective of the supplier is to maximise using the best planning strategy according to the characteristics of its production process.

5.1. Parameters for the supplier

The temporal features of the production system introduce different frozen horizons according to the considered decision. The delays associated to each decision are presented in table 1.

In this example we consider that the manager can modify its internal production during the current period. However, end-items internally produced can be delivered or added to the inventory at the following period (LP = 1). The use of the subcontractor requires the transmission of the information 2 periods in advance which induces that the decisions are frozen on the first two periods of the planning horizon. Then, the lead-time for the subcontractor is 2 periods. Extra-hours must be anticipated with a delay of 1 period and, obviously, are applied immediately. In order to make sure that rank 2 suppliers are able to manage their own production process, an anticipation of 4 periods is required for the supplier 1 (S1). An anticipation of 2 periods is required for the supplier 2 (S2). Thus, it is interesting to notice that the supplier will need to choose among its suppliers in order to balance the need for a reactive supplier (i.e. choosing the supplier 2) and minimising the purchasing cost as the first supplier is less expensive.

Decision	Lead time	Anticipation delay
Internal Production	1	
Subcontracting	2	2
Extra-hours		1
Rank 2 Supplier 1		4
Rank 2 Supplier 2		2

Table 1. Temporal parameters values

Unitary costs are associated to each decision variable:

Decision variable	Unitary cost	Decision variable	Unitary cost
Purchase of C1 at S1 ($f_{S1,C1}$)	2	Backorders (b_p)	20
Purchase of C2 à S1 ($f_{S1,C2}$)	1	Final product holding (h_p)	10
Purchase of C1 à S2 ($f_{S2,C1}$)	3	Production (u_p)	5
Purchase of C2 à S2 ($f_{S2,C2}$)	2	Subcontracting (st_p)	70
Holding cost of C1 (c_{C1})	1	Extra-hours (e)	30
Holding cost of C2 (c_{C2})	0,5		

Table 2. Cost structure for the simulation

The selling price of final products is 200 uc. The final product *p* is made of 1 component of type C1 ($\alpha_{P,C1} = 1$) and of 2 components of type C2 ($\alpha_{P,C2} = 2$). Finally, the internal production of final product p requires 2 time units ($R_p = 2$)

5.2. Design of experiments

In our example, the customer identifies two possible trends for the evolution of the market. The identification of these trends shows the will of the customer to facilitate the organisation of its supplier. In our example, the uncertainty remaining on the demand is characterised either by the possibility of occurrence of both trends and, moreover, by a flexibility of +/- 20% required for each trend. The first trend (T1) reflects a strong punctual increase of the demand with the acceptation of orders beyond the standard production capacity. Figure 4 shows the corresponding forecasts. At each period, the minimum, maximum and average values of the demand are given and compared to the cumulated capacity levels.

The second trend (T2) presented in figure 5 corresponds to a moderate increase as viewed by the customer. This punctual increase, expected for periods 20 to 25 is much lower than the previous one.

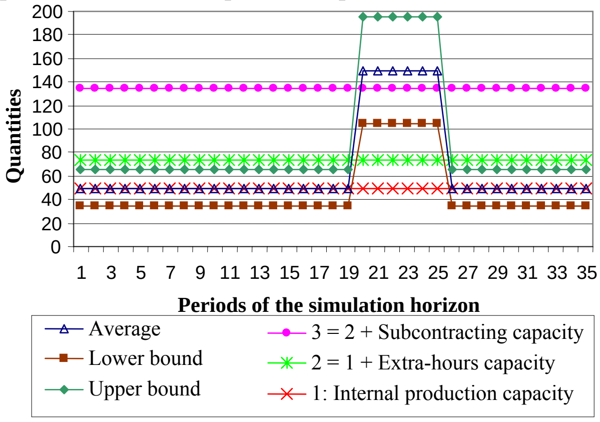

Figure 4. Trend 1 and production capacity levels

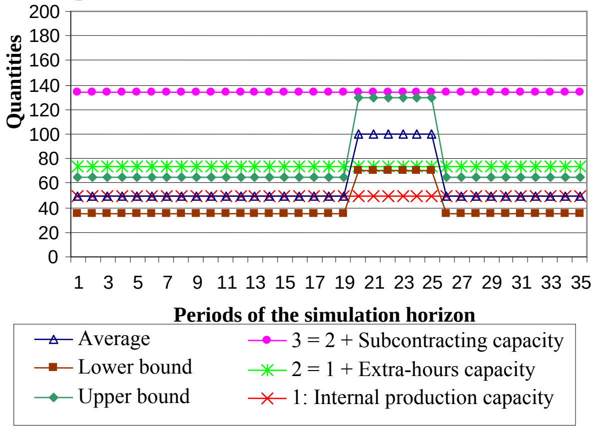

Figure 5. Trend 2 and production capacity levels

According to its height, the peak will have more or less influence on the planning process and may require different uses of production capacities (internal or subcontracted) while taking into account the production delays (Galasso, 2007).

In order to simulate several collaborative behavioural aspects, two behaviours of the customer are studied:

- a behaviour of overestimation of the demand. In that case, the customer will finally order the lower bound of the flexible demand. This behaviour is noted « Min »,
- a behaviour of underestimation of the demand in which the customer will finally order the upper bound of the flexible demand. This behaviour is noted « Max ».

As the planning process is proceed, the manager in charge of the planning process on the supplier side has a better understanding of the trend to which he will be confronted. Obviously, the improvement of this knowledge will be more or less fast according to its visibility on the firm demand characterised by the length of the firm horizon. The authors assume here that the supply chain has been defined consistently and that the visibility on the customer's final demand must enable the use of all decisional levers (i.e. use of extra-hours, subcontracting and use of both suppliers). Thus, a first collaborative action has been conducted in order to ensure that a common view on temporal parameters has been agreed by contract. Thus, taking into account the temporal parameters defined in table 1, this common view led both the supplier and the customer to adopt a length of 12 periods for the planning horizon in the simulations. Therefore, this length encompass the 4 periods necessary for the use of the subcontractor plus the four periods necessary to the use of the supplier 1 at rank 2 plus the 2 periods of the planning periodicity.

Firstly, the firm demand is known over a 4 period horizon. Over the following 8 periods, the demand is known under its flexible form. The percentage of flexibility is + and – 20 % of the average value.

In order to manage the uncertainty on the flexible demand, the supplier uses two planning strategies, S1 and S2, in its demand management process:

- S1: choose the maximum of the flexible demand
- S2: choose the minimum of the flexible demand

These strategies are evaluated against different scenarios for the behaviour of the customer. This evaluation is done running simulations that are designed as a combination of:

- a trend of the evolution of the demand (T1 or T2),
- a type behaviour for the customer (overestimation denoted « Min » or under-estimation denoted « Max » of the demand),

- a planning strategy of the supplier (concerning the choice of the maximal flexible demand denoted S1 or the choice of the minimal denoted S2).

The cost parameters and temporal parameters remain constant for each simulation.

5.3. Supplier risk evaluation

The gains obtained during the simulations with the use of the strategy S1 (i.e. the supplier integrates the maximum values of the demand) and S2 (i.e. the supplier integrates the maximum values of the demand) are presented in table 3. In this table, the best and the worst obtained for each behaviour of the supplier are shown in bold and are: 476 378 and 235 470 for the first strategy and of 403 344 and 264 853 for the second one.

	Trend 1		Trend 2	
	Scenario « Min »	Scenario « Max »	Scenario « Min »	Scenario « Max »
S1	245 201	**476 378**	**235 470**	444 191
S2	291 798	**403 344**	**264 853**	383 765

Table 3. Results obtained for FH = 4 and LH = 8

According to these results, it is possible to establish the risk diagram presented in figure 7 for a firm horizon length of 4 periods. To do so, it is necessary to calculate from which value of the realism coefficient α of the Hurwicz criterion a change of strategy is "recommended" (cf. figure 6).

In order to visualise this specific point, we draw the line of equation:

- $H_{S1} = (1-\alpha)\times 235\,470 + \alpha\times 476\,378$ for S1 and
- $H_{S2} = (1-\alpha)\times 264\,853 + \alpha\times 403\,344$ for S2.

It is now possible to establish the risk diagram (Figure 7). Firstly the α-axis symbolising the risk propension of the decision maker is drawn highlighting the value of the parameter α indicating a change of strategy (here for α = 0,29). Then, both strategies S1 and S2 are placed on the axis. Finally, the other criteria (Laplace and Savage) are placed in the diagram over the strategy that they recommend.

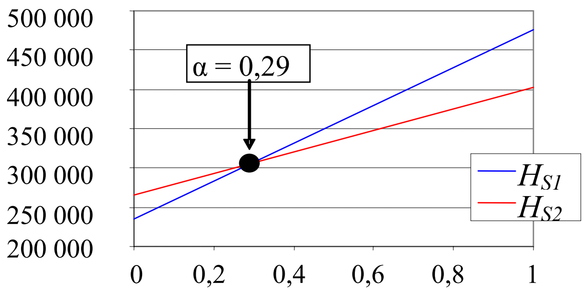

Figure 6. Point of change of strategy

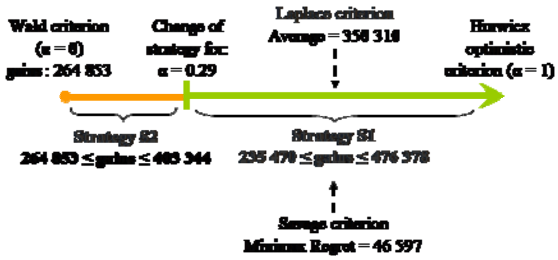

Figure 7. Risk diagram for FH=4 and LH=8

We can notice on this diagram that when pessimistic point of view is adopted (α tends to 0) the planning strategy using the minimal demand (S2) is recommended. The weighted Hurwicz criterion proposes a change in the strategy applied for an optimism degree of 0.29 (values comprised between 0 and 1). This value means that the strategy S2 may be envisaged by the supplier even if other criteria such as Laplace or Savage recommend the choice of the strategy S1. S1 is also recommended by the Hurwicz criteria for values over α = 0.29. Thus, the supplier will have en interest in requiring other information (i.e. information from the customer or upon the global market evolution) in order to determine if he should be pessimistic or not.

These results furnish further meanings to a simple simulation giving raw gains according to several scenarios. Indeed, in a first approach, it could be obvious that the higher the demand is, the higher the gains are. Nevertheless, disruptions may call into question the occurrence of a scenario leading to such gains and the raw results remains uncertain. Therefore, through the risk diagram, we afford not solely information regarding an interesting strategy to be applied but also an indication about the relevance of this choice.

5.4. Collaborative risk evaluation

In a collaborative perspective, we now, aim to highlight an interest for the customer inciting him to consolidate its demands. We aim at obtaining a solution in which no player has anything to gain by changing only his or her own strategy unilaterally). Thus, we look for a Nash equilibrium among the different strategies used by the customer and the supplier. So, we reiterate the previous design of experiments according to 3 different firm horizon length (6, 8 and 10) to which are added the corresponding flexible horizon length (6, 4 and 2) in order to keep a constant planning horizon length of 12 periods. For each set of simulations we obtain the gains and the cost of backorders. In order to compare the different scenarios, we extract for each strategy of the supplier (i.e. S1 and S2) and each potential visibility given by the customer, the worst and the most important backorder cost. These indicators correspond to the application of the Wald criterion in order to ensure a minimal gain and a maximal backorder cost in each simulation. The results are given in table 4.

Supplier strategy / Customer strategies (visibility)		S1		S2	
		Minimal Gain	Maximal Backorders	Minimal Gain	Maximal Backorders
4	8	235 470	14 260	264 853	96 040
6	6	256 284	13 620	264 853	52 140
8	4	262 128	12 300	264 853	30 700
10	2	264 557	12 300	264 853	19 940

Table 4. Comparative results for each couple of strategy and visibility

Then customer plays and figure 5 shows the results: the 3 first strategies are dominated by the fourth: onesolution is obtained for a visibility of 10 periods for the firm horizon and of 2 periods for the flexible horizon noted {10 ; 2}.

Supplier strategy / Customer strategies (visibility)		S1		S2	
		Minimal Gain	Maximal Backorders	Minimal Gain	Maximal Backorders
10	2	264 557	12 300	264 853	19 940

Table 5. Elimination of the dominated solutions for the customer

Then, the dominated solution (i.e. the use of the strategy S1) for the supplier is eliminated as depicted in table 6. Thus, the Nash equilibrium is obtained for the couple (S2 ; {10,2}).

Supplier strategy / Customer visibility			S2	
			Minimal Gain	Maximal Backorders
10	2		264 853	19 940

Table 6. Elimination of the dominated solutions for the supplier

This example illustrates the interest of integrating a cooperative approach in order to define a common strategy based on a couple of local strategies.

6. CONCLUSION

This article proposes a state of the art in order to propose a decision support for a collaborative management of the demand in a dyadic supply chain. A simulation tool has been defined in order to evaluate and compare gains and backorder levels obtained according to several behaviours of a supplier and a customer. In this customer-supplier relationship, the uncertainty inherent to the demand has an impact on the performance of the chain. In that way, both the customer and the supplier has an interest in collaborating through the definition of planning strategies consistent with the market evolutions and improving production conditions at the supplier level while reducing backorder costs for the customer.

A decision support methodology for the collaborative planning process is given firstly, through the use of a risk diagram according to the weighted Hurwicz criterion. This diagram gives more information than a simple evaluation of the plans established by the supplier according to the demand given by the customer. Indeed, the Hurwicz criterion introduces degrees of realism for which a planning strategy can be privileged.

Moreover, the customer role in the planning process for this dyadic supply chain is studied through the use of its decisional lever concerning the visibility he gives to its supplier. A game is led in order to find a Nash equilibrium. In this win-win situation, a couple of demand management strategies both for the customer and the supplier has been identified.

There are many perspectives to this work. Despite the planning process has been built as generic on purpose, wider numerical experiments can be considered. Roughly speaking, we expect a confirmation of the results presented in this article in terms of performance improvement when the collaboration in the customer-supplier relationship is improved. Furthermore, an extension to linear or networked supply chains could be investigated. Thus, we may obtain a set of strategies that can be used at each rank of the chain while improving its global performance.

REFERENCES

Bartezzaghi, E. and R. Verganti, 1995. Managing demand uncertainty through order overplanning. *International Journal of Production Economics*, 40, p. 107-120.

Brindley, C. (Ed.), 2004. *Supply chain risk*. MPG Books Ltd.

Christopher, M. 2003. Understanding Supply Chain Risk: A Self-Assessment Workbook. Cranfield University, School of Management, http://www.som.cranfield.ac.uk/som/research/centres/lscm/risk2002.asp , visited January 17, 2008.

Dudek G. and Stadtler H, 2005. Negotiation-based collaborative planning between supply chains partners, *European Journal of Operational Research* 2005, Vol. 163, n°3, pp. 668-687.

François, J. and F. Galasso, 2005. Un cadre générique d'analyse des relations dans la chaîne logistique interentreprises. *Proceedings from the 6th Congrès international de génie industriel,* Besançon, France (in french).

Galasso, F., Mercé, C. and B. Grabot, 2006. Decision support for supply chain planning under uncertainty. *Proceedings from the 12th IFAC International Symposium Information Control Problems in Manufacturing (INCOM),* St Etienne, France, 3, p. 233-238.

Galasso, F., 2007, *Aide à la planification dans les chaînes logistiques en présence de demande flexible*. Thèse de Doctorat, Institut Nationale Polytechnique de Toulouse, France (in french).

Génin, P., Thomas, A. and S. Lamouri, 2007. How to manage robust tactical planning with an APS (Advanced Planning Systems). *Journal of Intelligent Manufacturing*, 18, p. 209-221.

Huang, G. Q., Lau, J. S .K. and Mak K. L, 2003. The impacts of sharing production information on supply chain dynamics: a review of the literature. *International Journal of Production Research*, Vol. 41, n°7, pp. 1483--1517.

Lapide, L, 2001. New developments in business forecasting, *Journal of Business Forecasting Methods & Systems*, Vol. 20, n° 4, pp. 11-13.

Lee, H.L., Padmanabhan, P. and Whang. S, 1997. Information Distortion in a Supply Chain: The Bullwhip Effect, *Management Science*, Vol. 43, pp. 546-558.

Mahmoudi, J., 2006. *Simulation et gestion des risques en planification distribuée de chaînes logistiques : application au secteur de l'électronique et des télécommunications.* Thèse de Doctorat, Sup'aero, France, In french.

McCarthy, T. and Golicic S, 2002. Implementing collaborative forecasting to improve supply chain performance, *International Journal of Physical Distribution & Logistics Management*, Vol. 32, No. 6, pp. 431-454.

Moyaux, T, 2004. *Design, simulation and analysis of collaborative strategies in multi-agent systems: The case of supply chain management*, PhD thesis, Université Laval, Ville de Québec, Québec, Canada.

Mula, J., Poler, R. and J.P. Garcia, 2006. MRP with Flexible Constraints: A Fuzzy Mathematical Programming Approach, *Fuzzy Sets and Systems,* 157, pp. 74-97.

Odette, 2007. http://www.odette.org, visited January 17, 2008.

Ritchie, B. and C. Brindley, 2004. *Risk characteristics of the supply chain – a contingency framework.* Brindley, C. (Ed.). Supply chain risk. Cornwall: MPG Books Ltd.

Rosetta, 2007. http://www.rosettanet.org, visited January 17, 2008.

Rota, K., Thierry, C. and G. Bel, 2002. Supply chain management: a supplier perspective. *Production Planning and Control*, Vol. 13, n°4, pp. 370-380.

Shirodkar S. and Kempf K, 2006. Supply Chain Collaboration Through shared Capacity Models, *Interfaces*, Vol. 36, No. 5, September-October 2006, pp. 420-432.

Småros, J, 2005. *Information sharing and collaborative forecasting in retail supply chains*, PhD thesis, Helsinki University of Technology, Laboratory of Industrial Management.

Tang, C.S, 2006. Perspectives in supply chain risk management, *International Journal of Production Economics*, Vol 103, pp. 451-488.

Vics, 2007. http://www.vics.org/committees/cpfr/, visited January 17, 2008.

Ziegenbein, A. and J. Nienhaus, 2004. Coping with supply chain risks on strategic, tactical and operational level. *Proceedings of the Global Project and Manufacturing Management Symposium*. Richard Harvey, Joana Geraldi, and Gerald Adlbrecht (Eds.), Siegen, pp. 165-180.